Model Uncertainty of Wake models in AEP predictions

Murcia, Juan Pablo; Réthoré, Pierre-Elouan; Hansen, Kurt Schaldemose; Natarajan, Anand; Sørensen, John Dalsgaard

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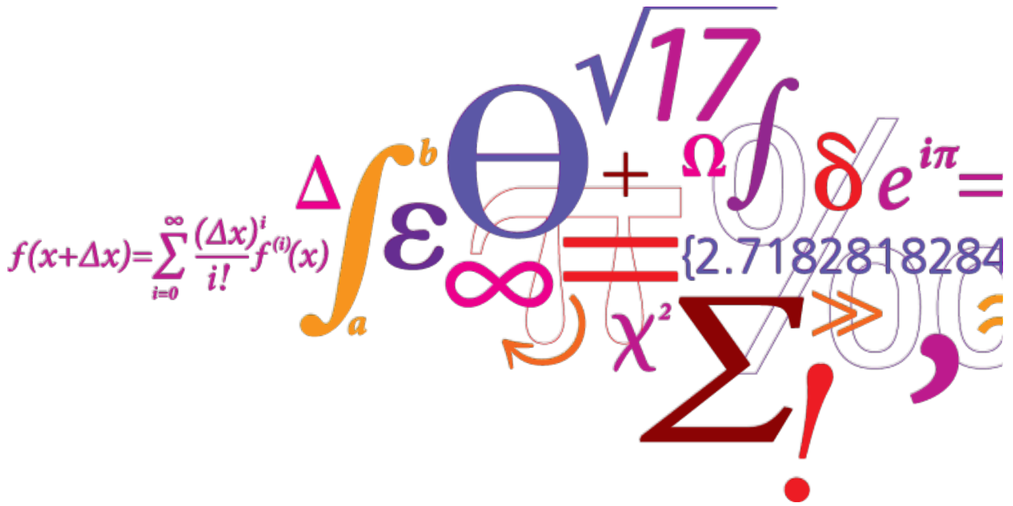
Juan Pablo Murcia (jumu@dtu.dk)
Pierre-Elouan Réthoré
Kurt Hansen
Anand Natarajan
John D. Sørensen



DTU Wind Energy
Department of Wind Energy

Messages in this talk

1. What is wake model validation?
2. Is it possible to predict the wake model error on AEP for an arbitrary offshore wind power plant?
3. Use of SCADA data to validate wake models

AEP is proportional to the E(P_WF)

$$\mathrm{AEP}_{\mathrm{WF}} = N_h \mathbb{E}(P_{\mathrm{WF}})$$

Challenges

- Comparing averaged values is not trivial
- Is the model predicting the right distribution of power?

Wake model error can be obtained by comparing the distribution of P_WF

Measured (SCADA)
vs
Predicted (e.g. NOJ)

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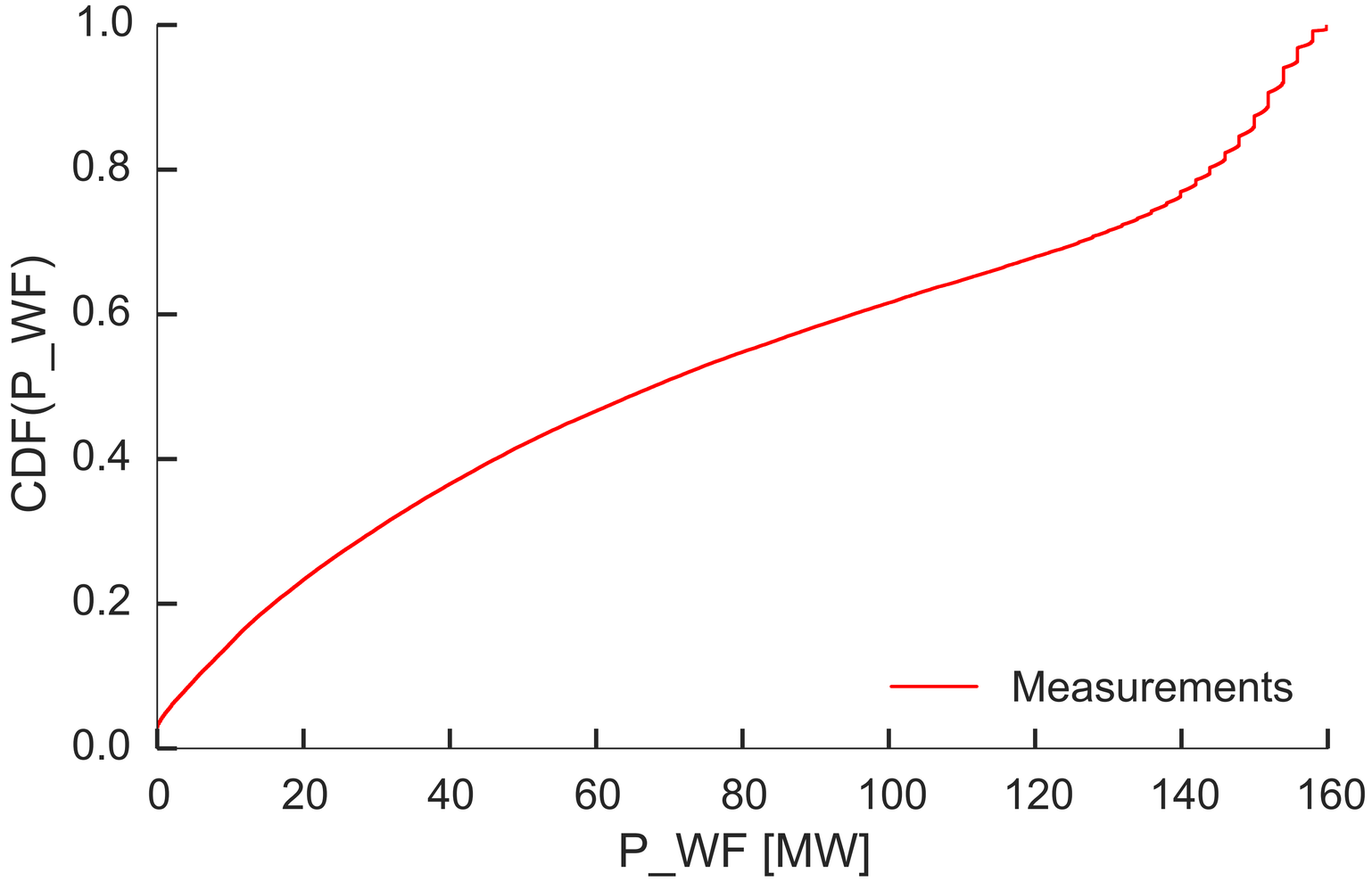
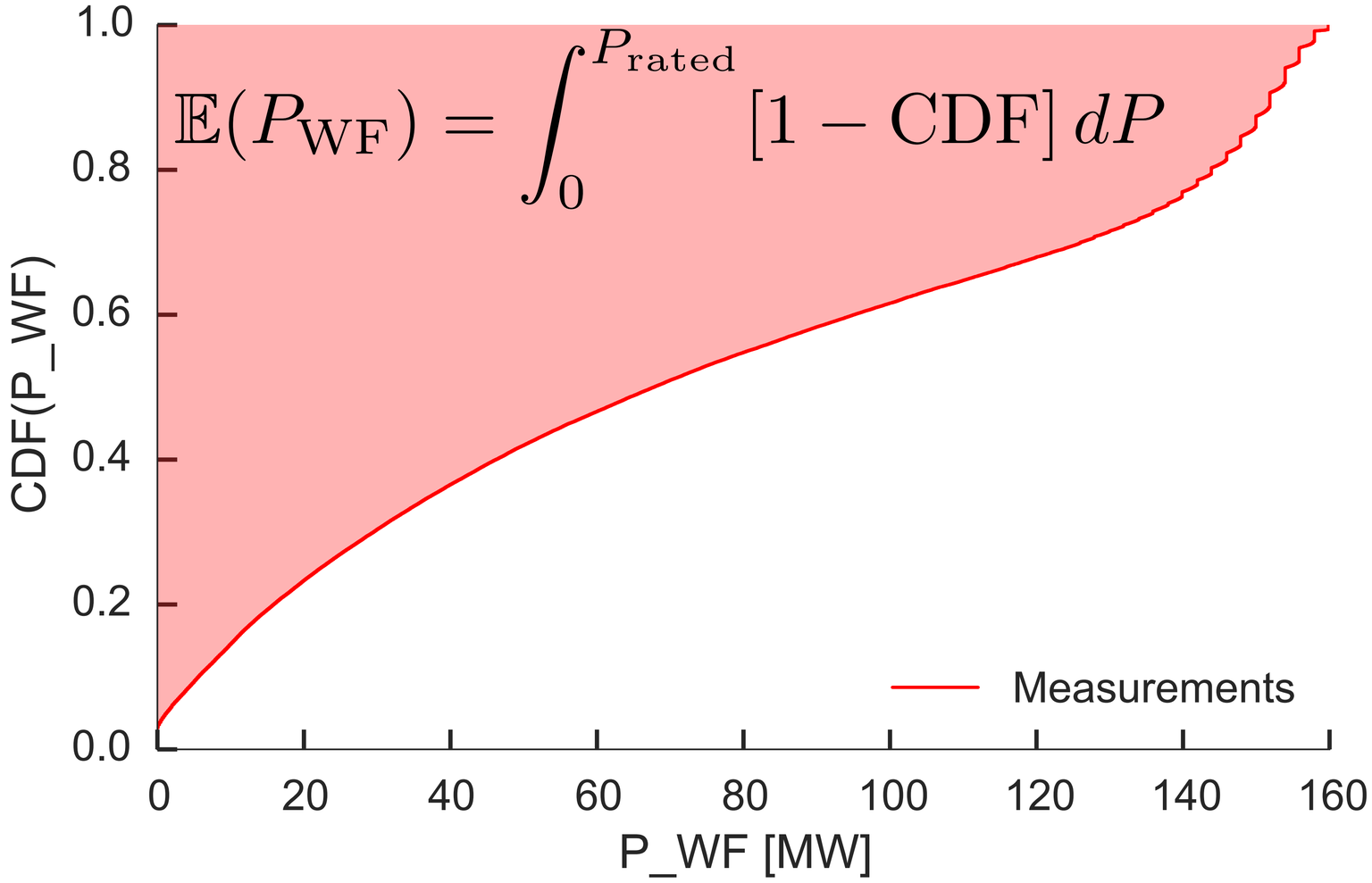
Distribution of power

- Cumulative probability distribution of 10 min power production from SCADA



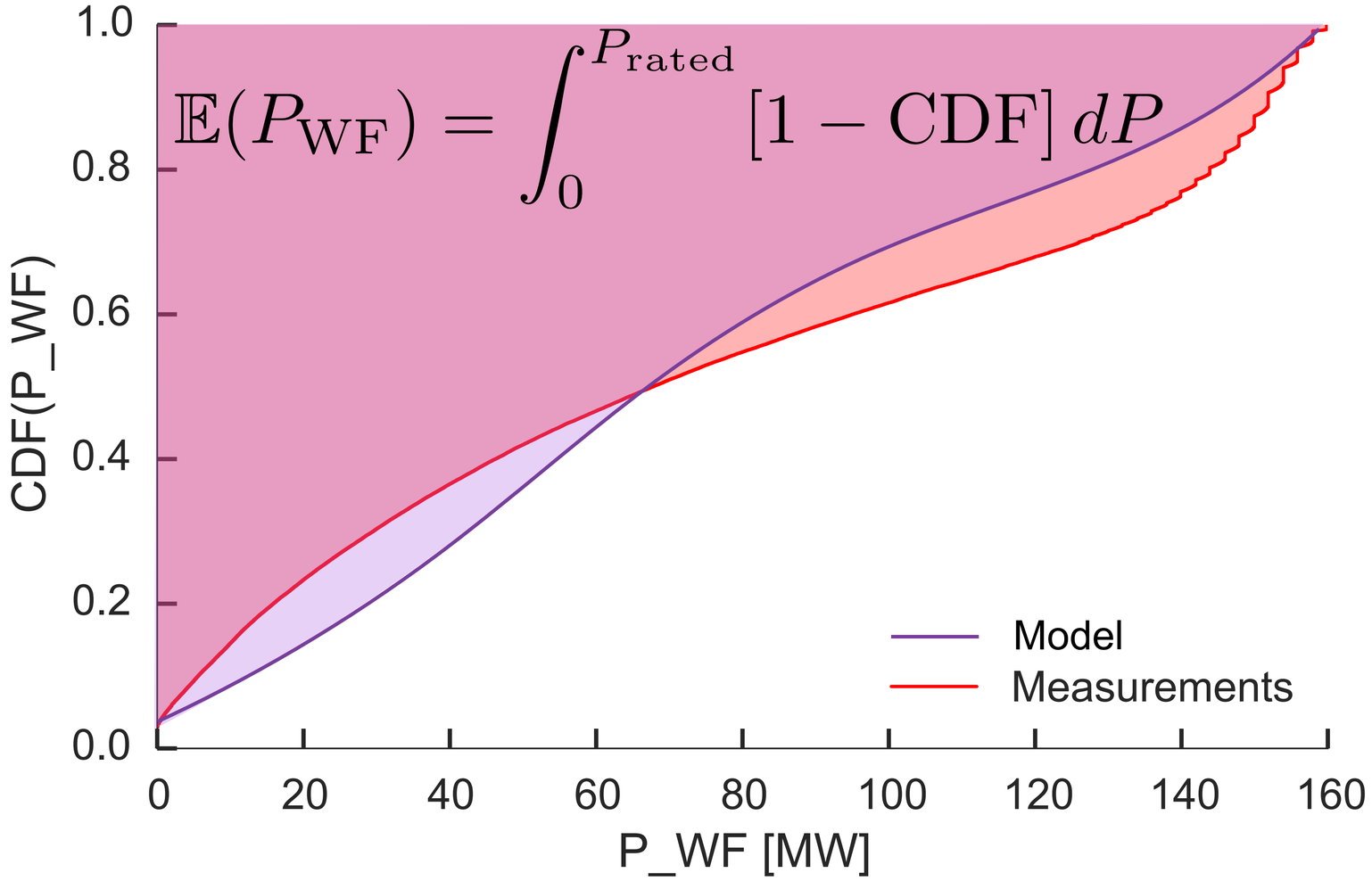
Distribution of power

- Expected value of power is the area above CDF



Is this a good model??

- Compare the areas



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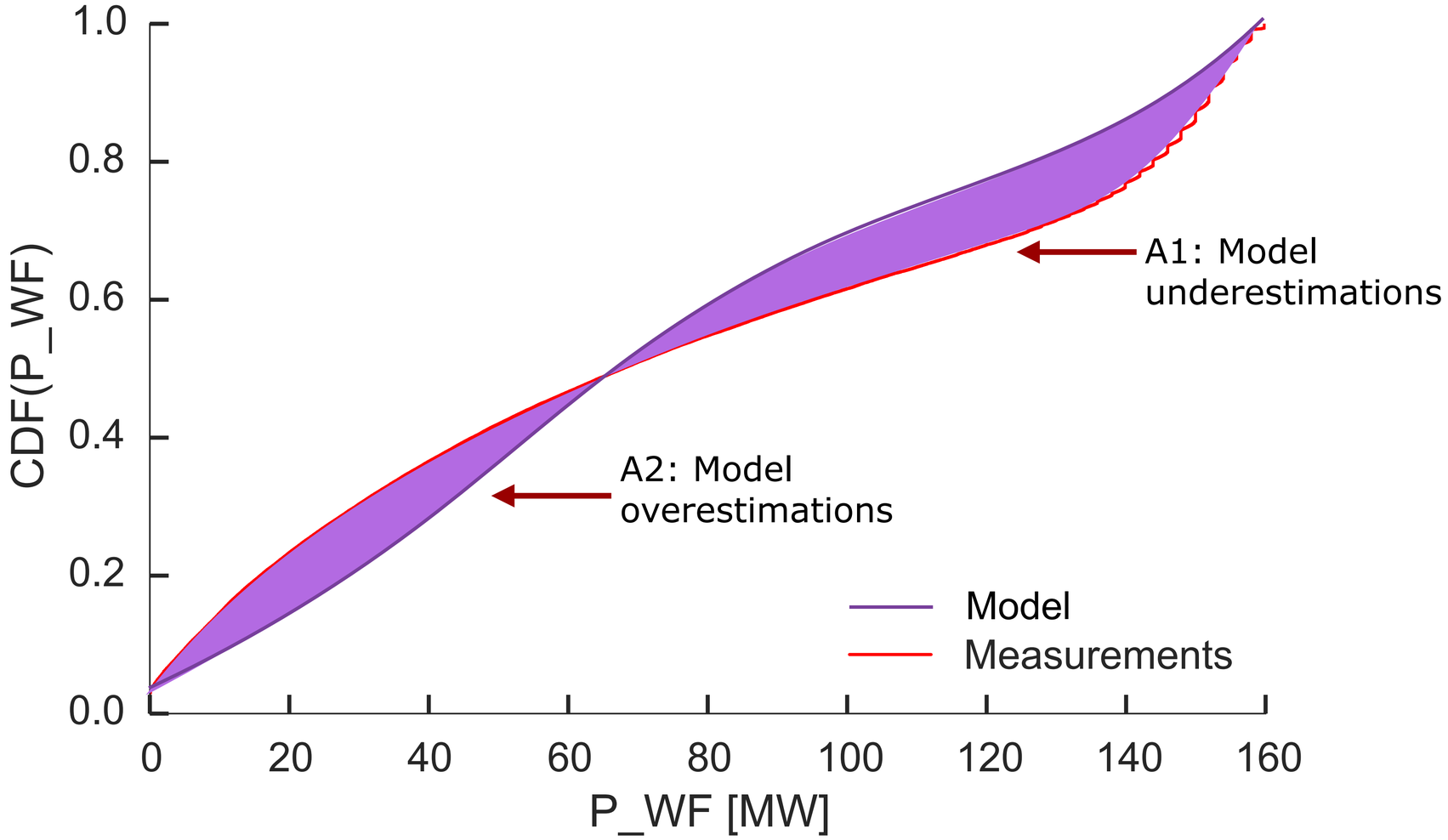
Is this a good model?? Compare the areas

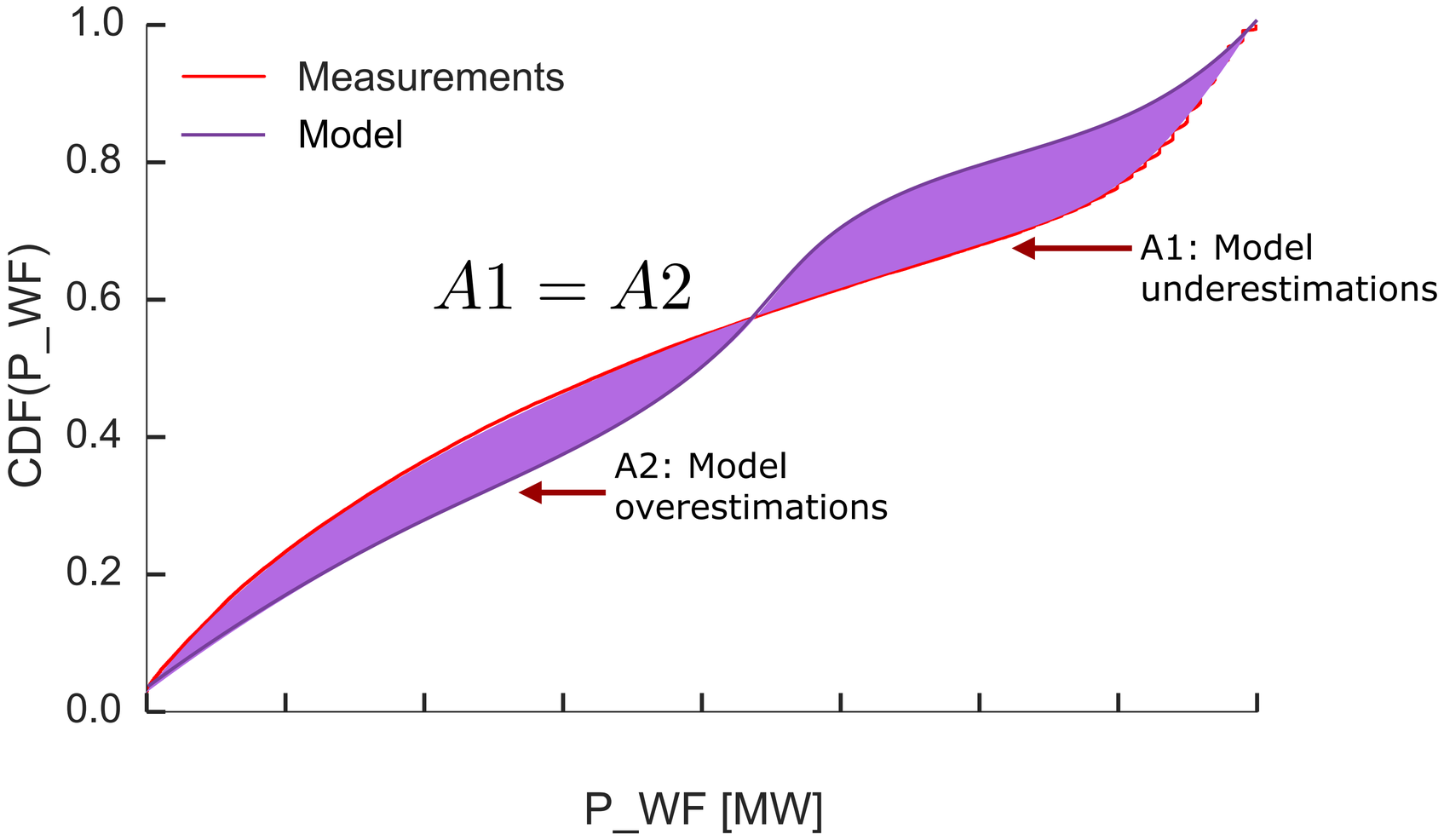
$$\mathbb{E}(P_{\mathrm{WF}})_{\mathrm{meas}} - \mathbb{E}(P_{\mathrm{WF}})_{\mathrm{model}} = A1 - A2$$



What is the problem?

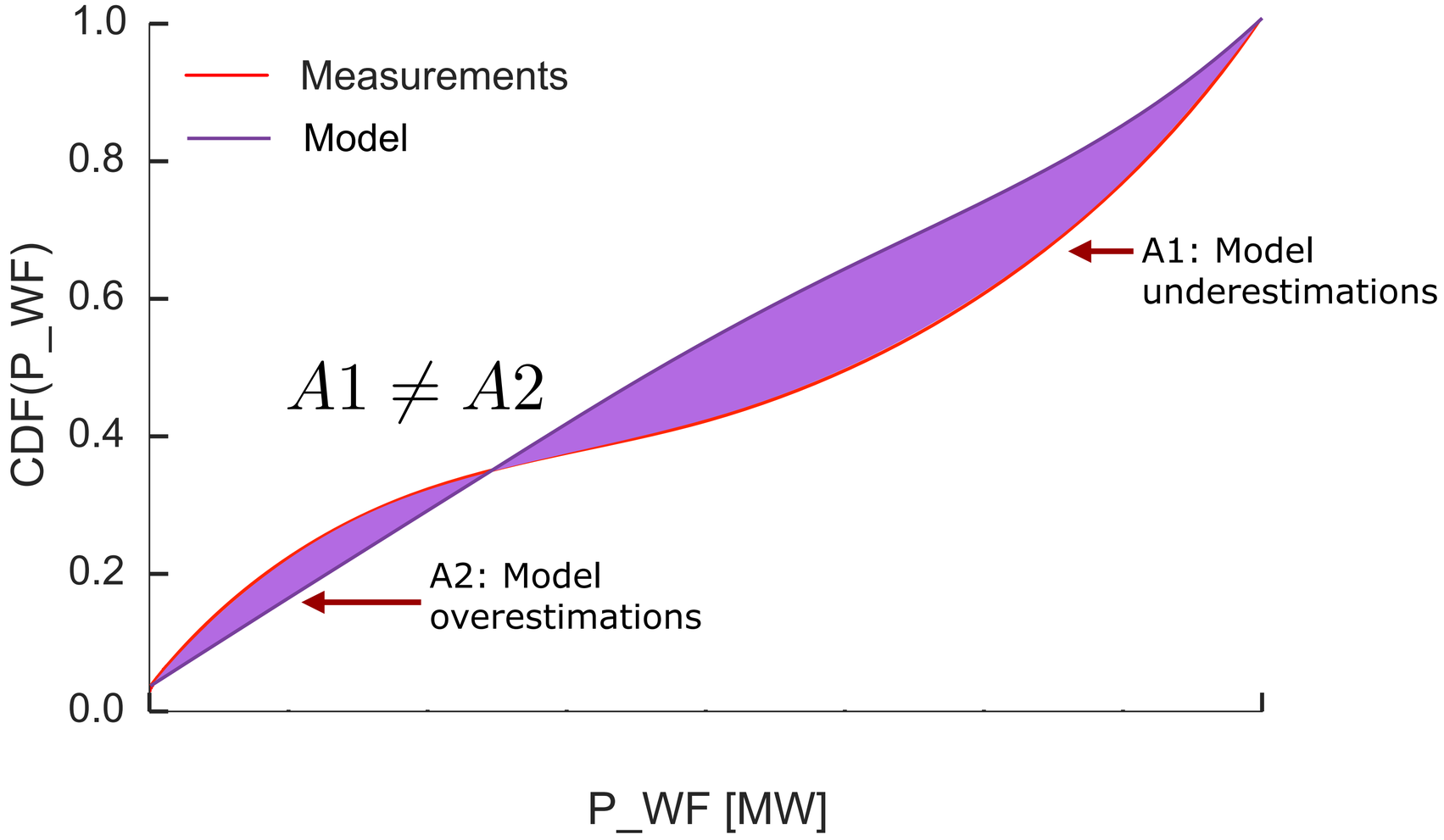
Calibration at a given WF1

$$\mathbb{E}(P_{\mathrm{WF}})_{\mathrm{meas}} = \mathbb{E}(P_{\mathrm{WF}})_{\mathrm{model}}$$



Calibrated model fails at WF 2

$$\mathbb{E}(P_{\mathrm{WF}})_{\mathrm{meas}} \neq \mathbb{E}(P_{\mathrm{WF}})_{\mathrm{model}}$$



Area validation metric as a way to estimate model error

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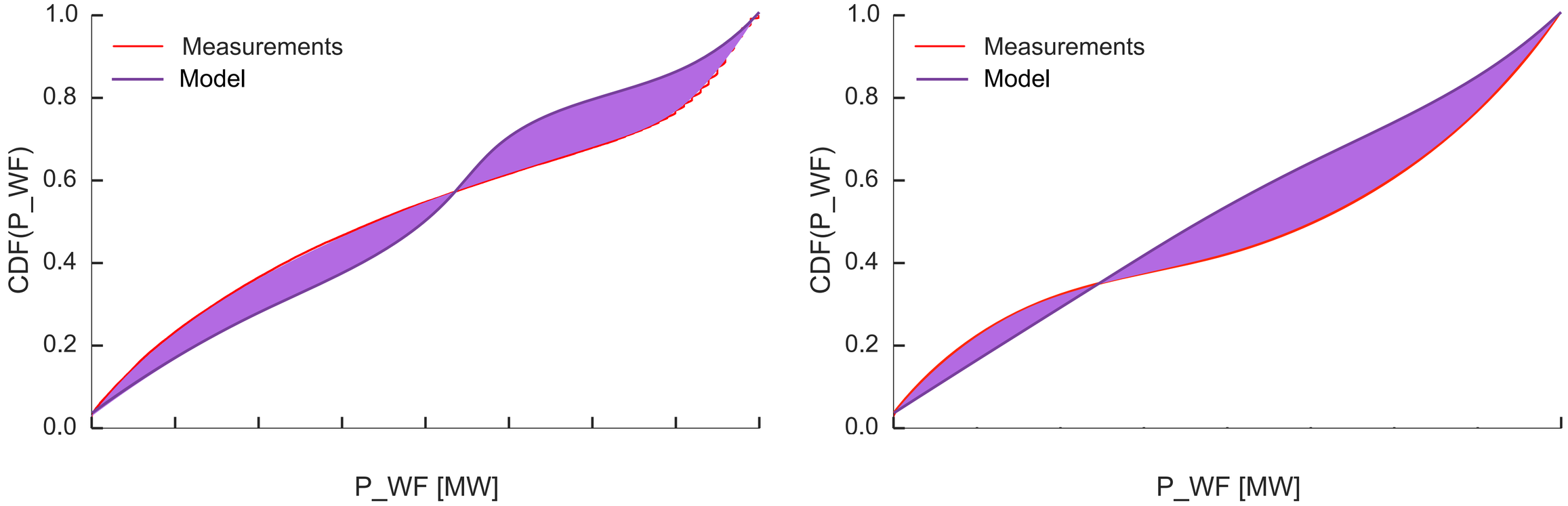
Calibration at a given WF1

- Area between the distributions as model uncertainty
- Proposed at SANDIA [Oberkampf]

~~$$\mathbb{E}(P_{\mathrm{WF}})_{\mathrm{meas}} - \mathbb{E}(P_{\mathrm{WF}})_{\mathrm{model}} = A1 - A2$$~~

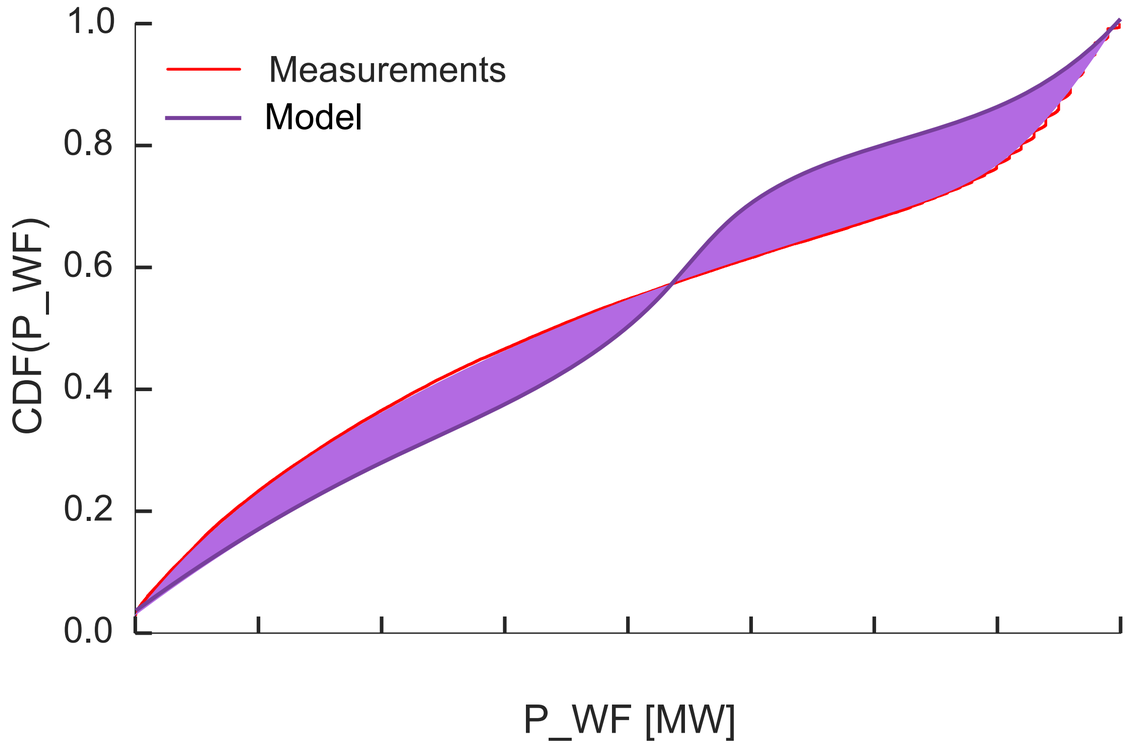
$$\mathrm{AVM} = A1 + A2$$

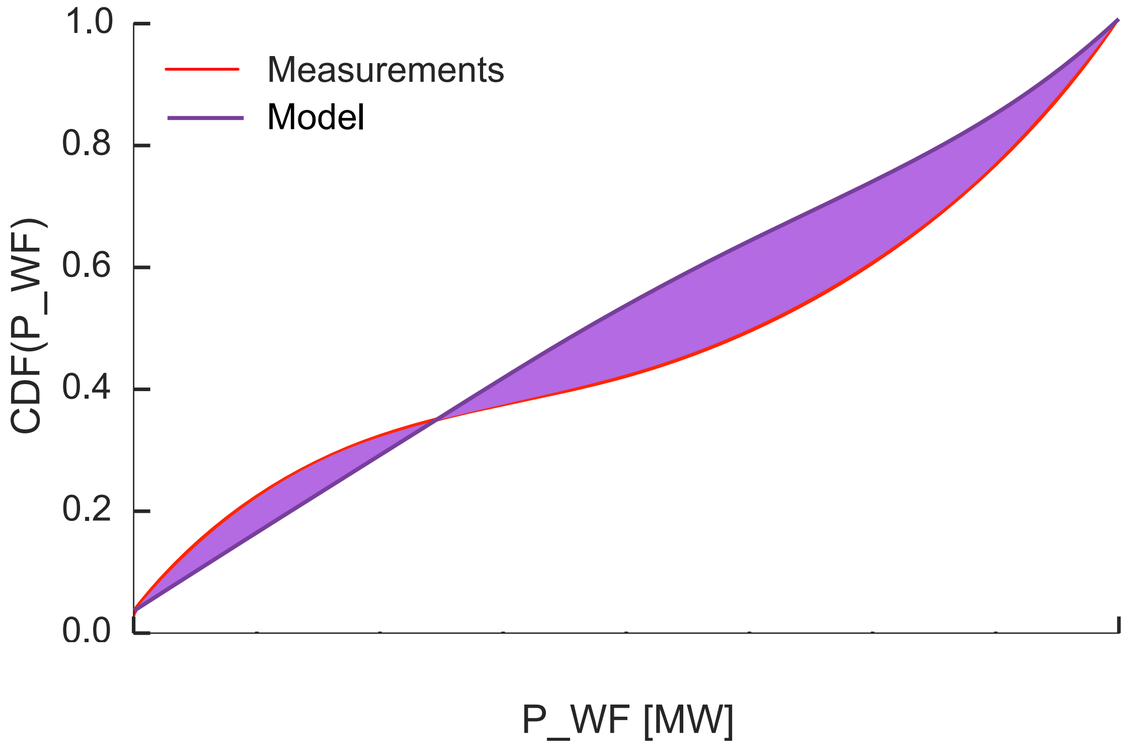


Area Validation Metric (AVM)

- Gives a conservative estimation of model uncertainty

$$\mathbb{E}(P_{\mathrm{WF}})_{\mathrm{meas}} \in \mathbb{E}(P_{\mathrm{WF}})_{\mathrm{model}} \pm AVM$$





Can the model uncertainty be predicted??

YES
Build a model validation domain

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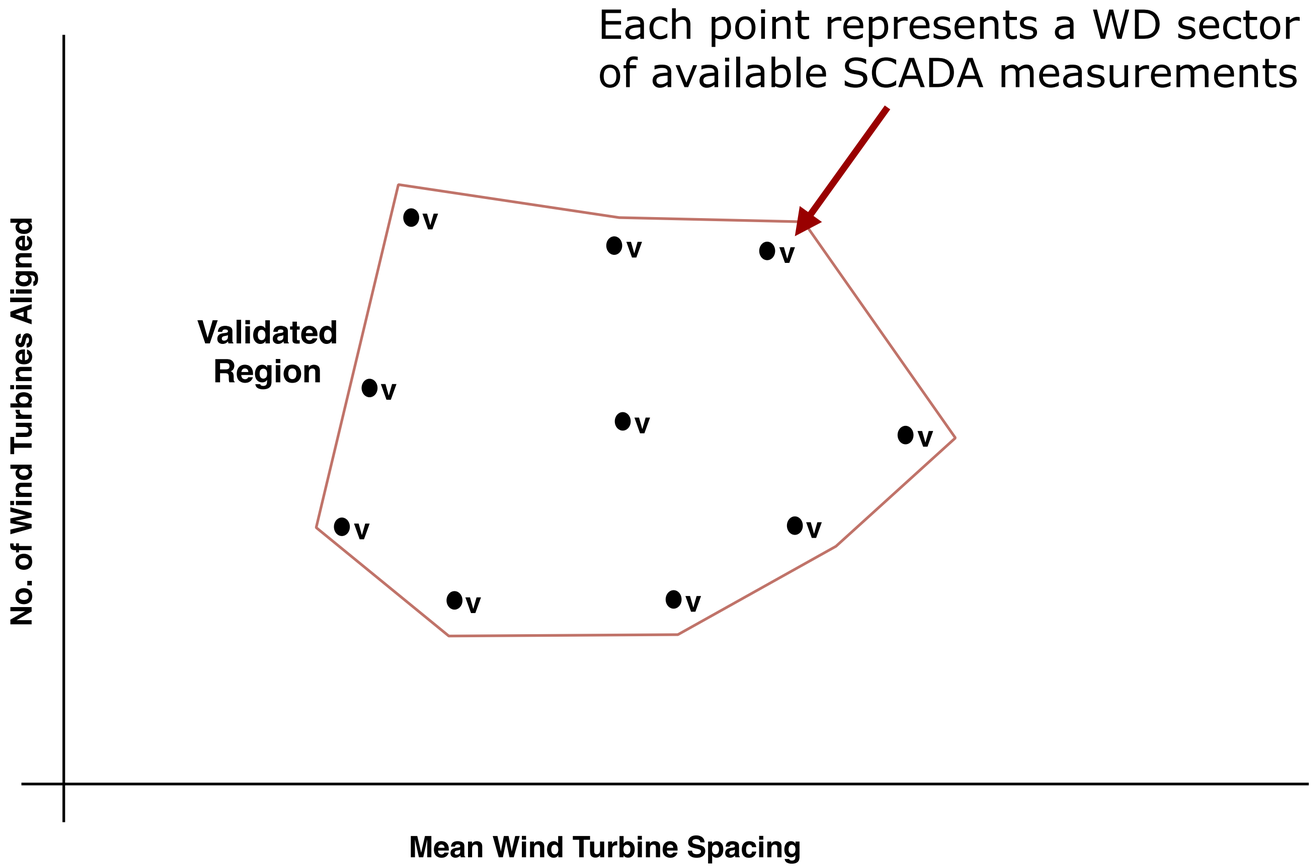
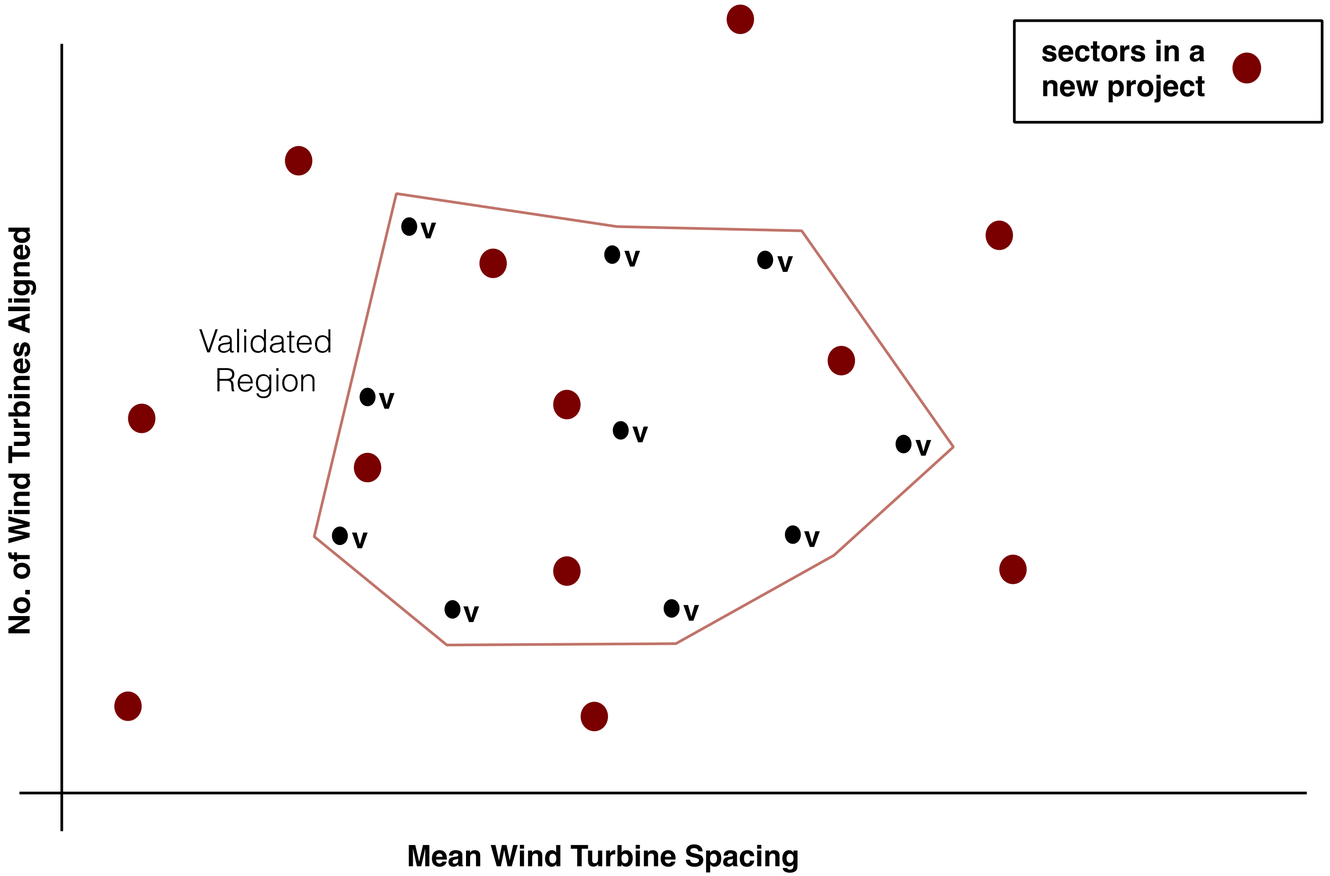
Wake Model Validation

- Continuos process of extending the **validated region**



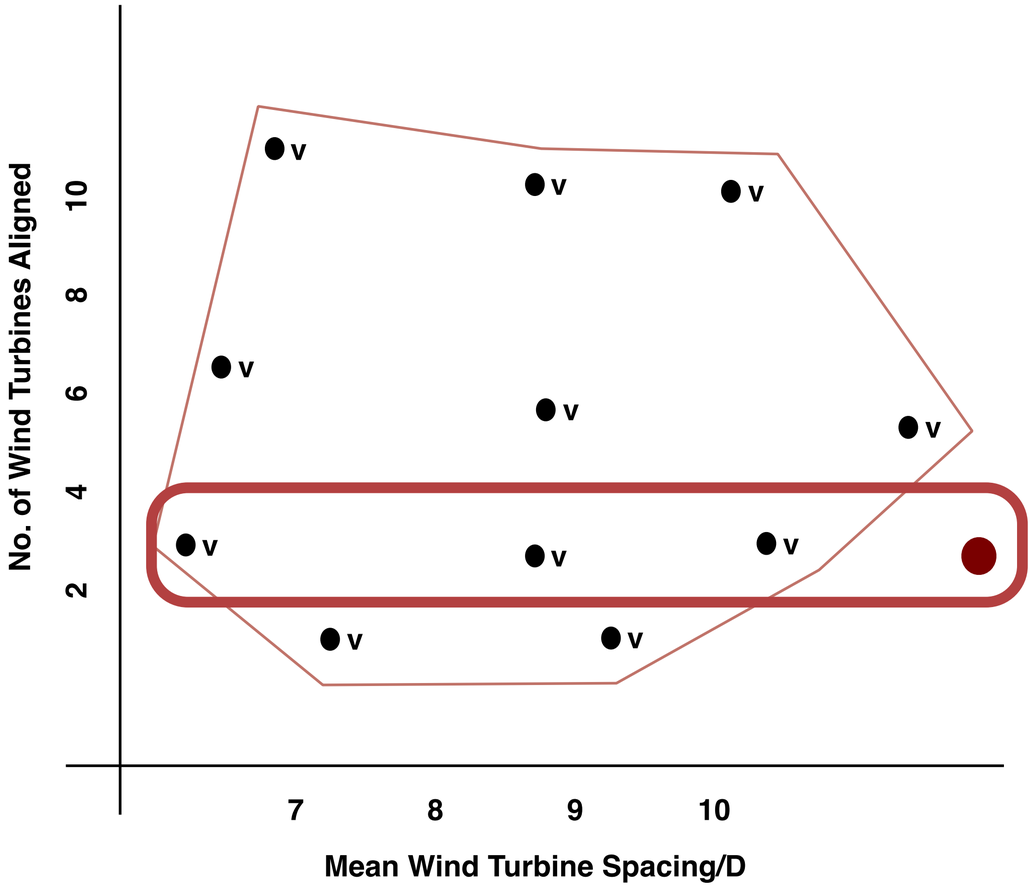
Wake Model Validation

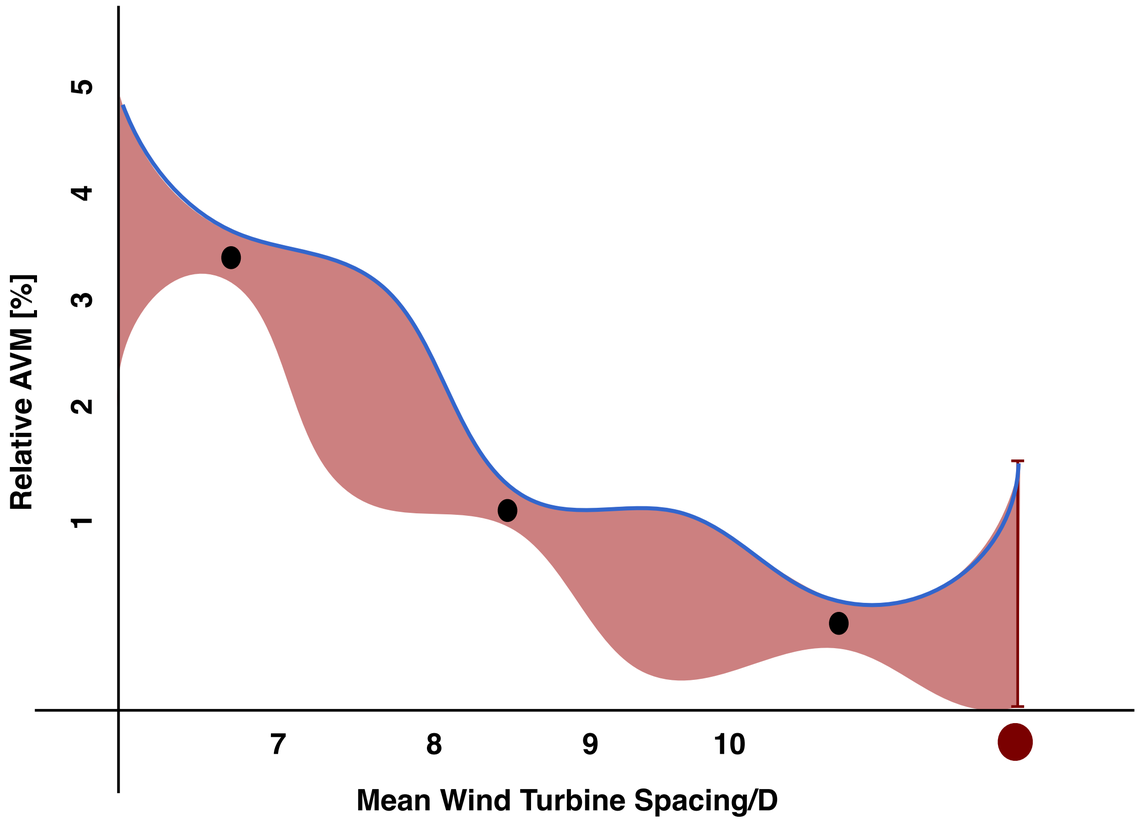
- Continuos process of extending the **validated region**



Validation Region of a wake model

- Used to estimate the error in the prediction of the new project





Example using Horns Rev 1

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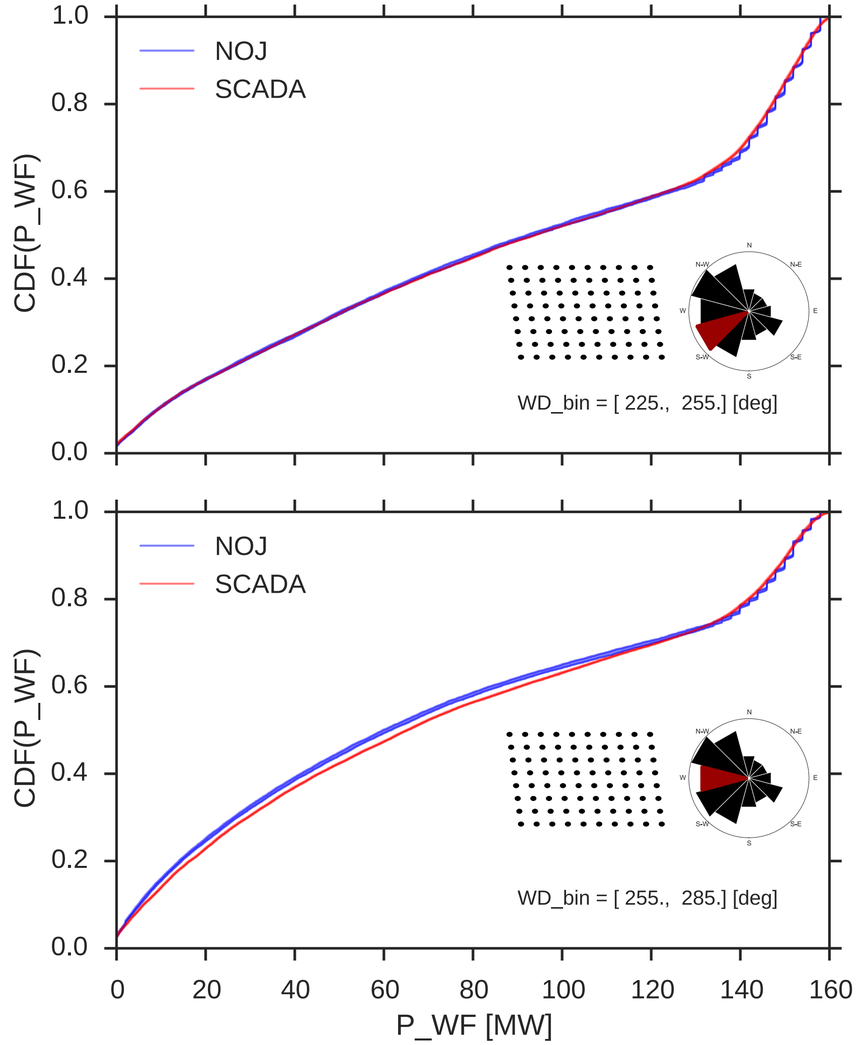
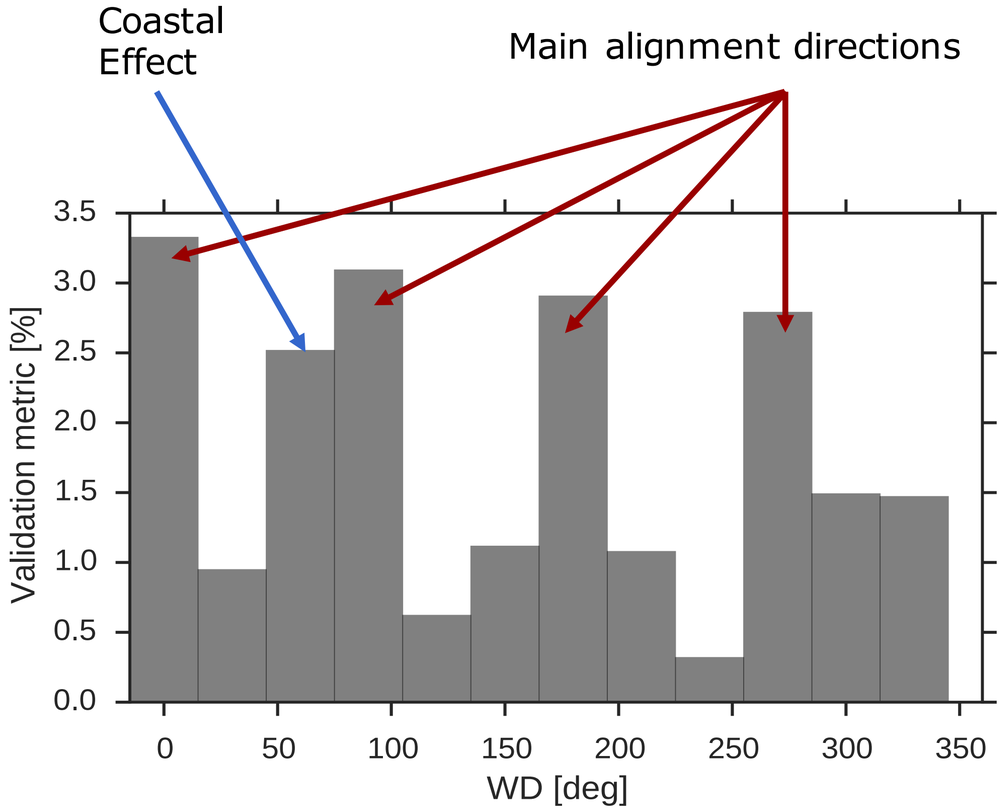
Area validation metric (AVM) in Horns Rev 1

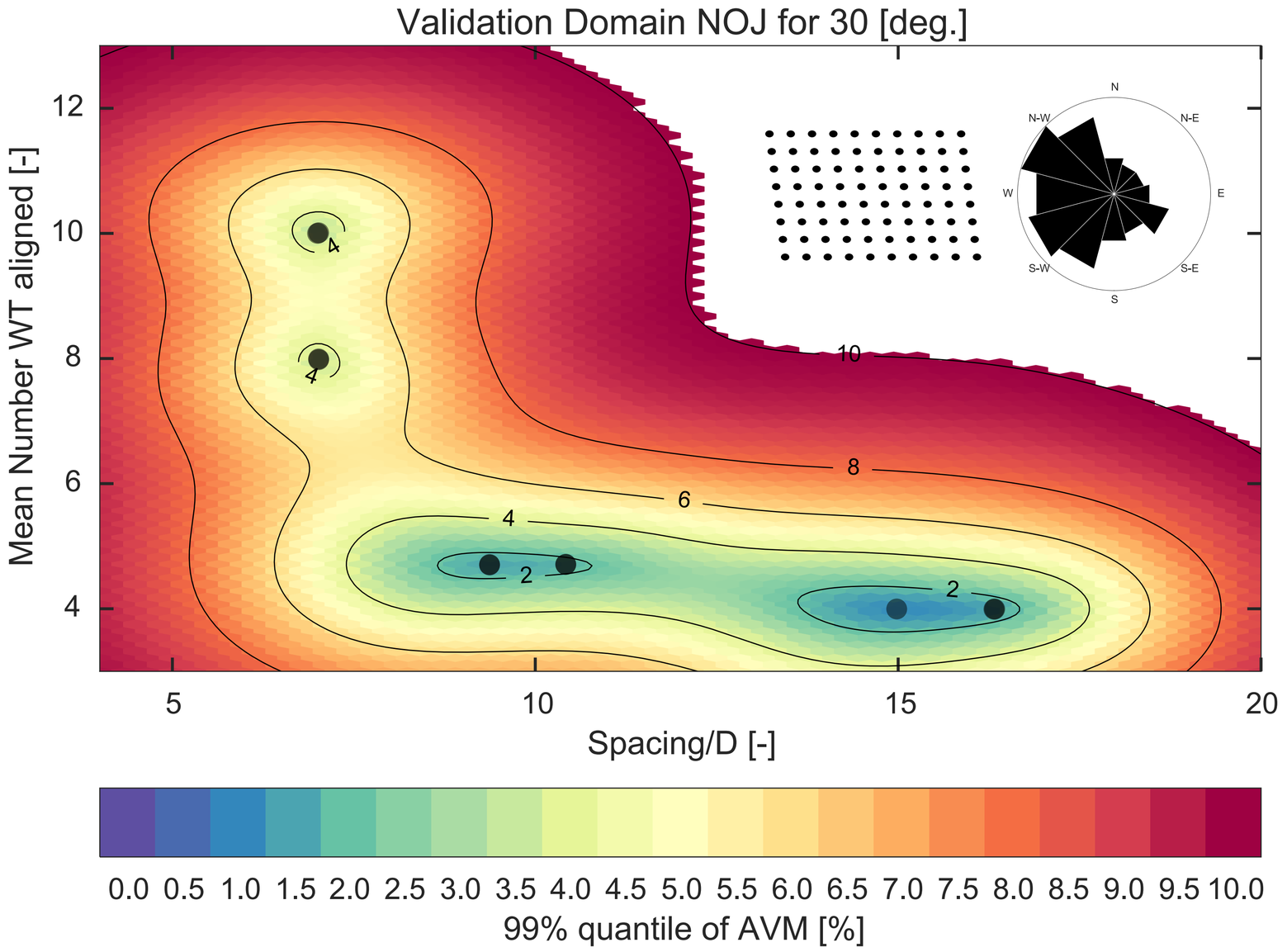
- AVM is used to define/predict the wake model uncertainty



$$\mathbb{E}(P_{\mathrm{WF}})_{\mathrm{meas}} \in \mathbb{E}(P_{\mathrm{WF}})_{\mathrm{model}} \pm AVM$$



NOJ Wake Model Validation Domain



The error of a wake model can be predicted

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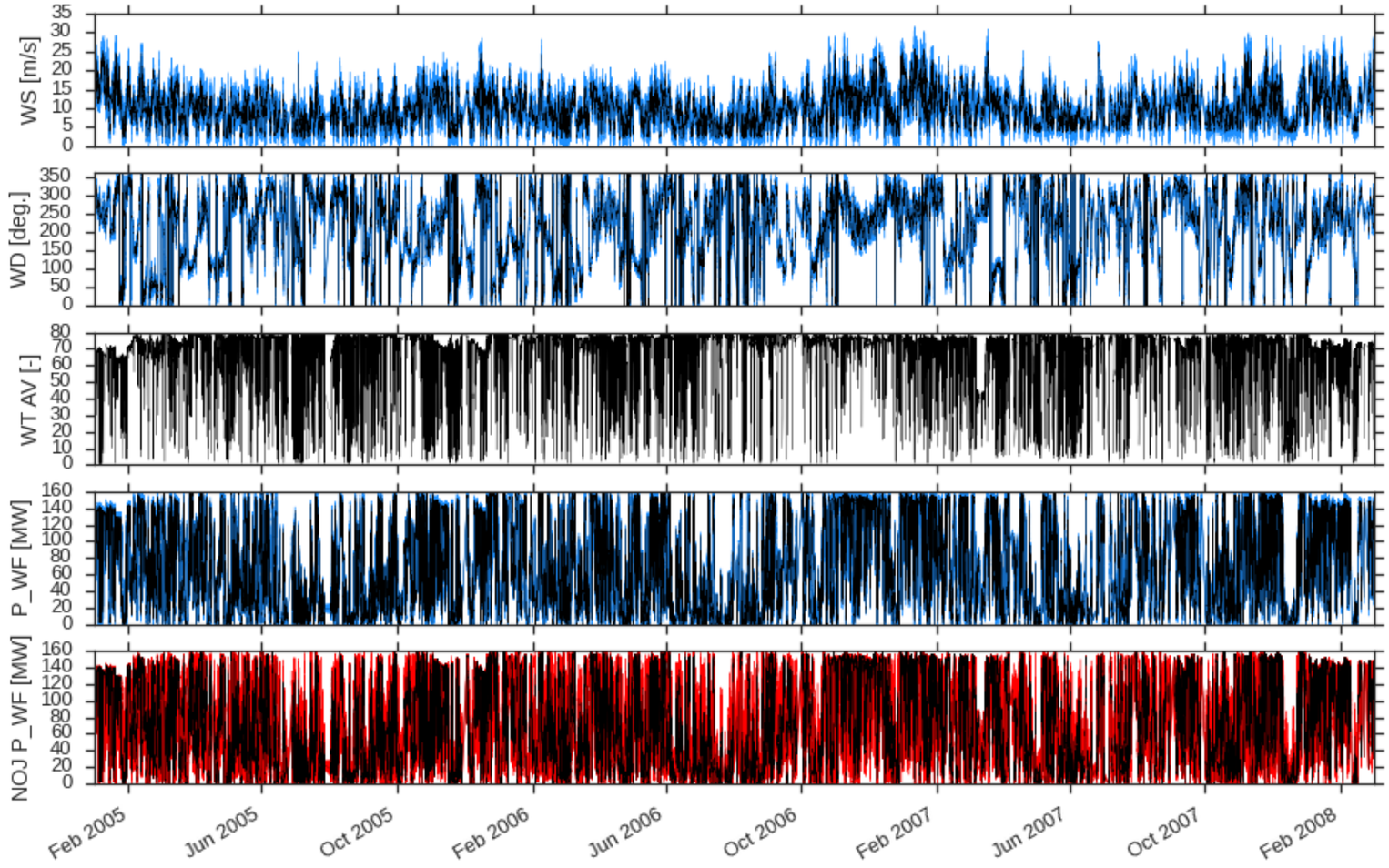
The elephant in the room

How do you get the CDF(P)?

Power distribution Re-analysis of SCADA

- General method to reconstruct the time series from SCADA of offshore WF's



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Conclusions

1. Validation based on the distribution of P_WF for each sector
2. Use SCADA data to build validation region (for every model)
3. Wake model error on AEP can be predicted for an arbitrary wind power plant, but you will need SCADA data

- **We invite you to give us access to offshore SCADA data**

  They will be anonymously used
- We offer you open source wake models (FUSED-Wake)
- Validation regions updated with the new observations for several models

Visit https://github.com/DTUWindEnergy/FUSED-Wake

Thank you for your attention

Please ask questions

Or write me an email:

Juan Pablo Murcia

jumu@dtu.dk